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DAMAGE OF SOILS BY MILITARY ACTIONS AND PROSPECTS OF THEIR RESEARCH AND RESTORATION

The types of negative impact of military actions on the ecological condition of soils are considered. Directions and sequence of soil condition study in the post-war period are determined. Stages and methods of restoration of war-damaged soils are outlined.

Keywords: *soils, military actions, environmental monitoring, soil restoration.*

Розглянуто види негативного впливу військових дій на екологічний стан ґрунтів. Визначено напрямки і послідовність дослідження стану ґрунтів у пост воєнний період. Окреслено етапи та методи відновлення пошкоджених війною ґрунтів.

Ключові слова: *ґрунти, військові дії, екологічний моніторинг, відновлення ґрунтів.*

Introduction. The greatest and most valuable wealth of Ukraine is its fertile lands, unique Ukrainian chernozems, which are determined by a significant area of arable land and climatic parameters that guarantee a high yield of agricultural crops.

As a result of active military operations (movement of military equipment, military engineering work, temporary or long-term deployment of military units, partial or complete destruction of military equipment, defensive structures, of military and medical depots, industrial, economic and infrastructure facilities, fire effects of varying intensity, minefields and detonation of munitions, fires) there is a change in the original properties of the soil cover, which directly affects the possibilities of its economic use, while effective reclamation in the post-war period can take a very long time [1, p. 208]. In addition, a serious problem is the formation of waste (military, medical, domestic, construction) arising as a result of military operations, and which causes an additional threat of the introduction of toxic compounds and elements into the soils.

Consequences of munitions explosions on soils: 1) *an explosive wave* causing destruction of vegetation, formation of sinkholes, compaction of soils, death of soil fauna, which in turn causes destruction of soil structure and change of hydrological regime, that is, it causes soil erosion, which together with climate change leads to desertification; 2) *chemical pollution*, which also causes the death of soil fauna and flora.

Object and subject of research. The object of the study is the destruction of soils by military actions. The subject of the study is the optimal organization of complex ecological monitoring of the condition of soils after military operations and methods of their recovery.

Discussion and Results. Contamination of the ground cover of the earth leads to a violation of its basic physico-chemical and biological properties (Zentelis, R., et al., 2014). Military operations cause nitroaromatic explosive compounds to enter the soil, such as trinitrotoluene (TNT), octogen (1,3,5,7-tetranitro-1,3,5,7- tetraazocyclooctan, cyclotetramethylene-tetranitroamine, HMX) and 1,3,5-trinitroperhydro-1,3,5-triazine (RDX) Azines, for which there are ecological concentration limits due to

their toxicity for environmental objects and human health. In addition to these components, explosives can contain nitro compounds (picric acid), nitrate acid salts (ammonium nitrate), fulminic acid (mercury fulminate), azide acid - HN_3 (lead azide), organic esters of nitrate acid (nitroglycerin, pyroxylin, nitroglycol). In the environment, these compounds are resistant to evaporation, hydrolysis and biological degradation, they are absorbed by plants or washed into groundwater. In addition, the transformation products of nitroaromatic compounds are not only toxic, but also have a higher resistance than their starting substances. It is known that trinitrotoluene.(TNT) and its conversion products significantly affect the soil fauna, suppress the microbiological activity of the soil at various concentrations, and also adversely affect the edaphone of the soil ecosystem (edaphone – a collection of all living creatures of the soil) (the LC_{50} for earthworms for *Lumbricina* is 200-400 mg/kg) [2, p.143]. In this case, there is a suppression of germination, growth and development of plants due to the presence of nitroaromatic compounds in the soil.

Therefore, the processes of transformation of the soil cover are caused by military actions include significant changes in physical, physico-chemical, ecological and biological indicators. Thus, in the conditions of military actions, there is a decrease in the quality and area of agricultural lands, first of all, the soil and plant cover is disturbed, the landscape and orographic parameters of the territories change [3, p.85]. Due to prolonged shelling, the atmosphere is contaminated by the products of ammunition explosions with the formation of a number of dangerous elements that become sources of contamination of the surface layer of soils. During explosions of military rockets, artillery shells and mines, a number of chemical compounds are formed: carbon monoxide, carbon dioxide, water vapor, nitrogen, etc. In addition, a large amount of toxic organics is formed, the surrounding soils are oxidized, wood, residential and commercial structures are burned. In addition, the consequence of military actions is the presence in the environment of such toxic compounds as sulfur and nitrogen oxides, which during oxidation lead to the formation of acid rains, and can also change the acidity of the soil, cause burns to plants and mucous tissues of the respiratory organs of people, birds and animals.

A dust-gas cloud containing a large amount of harmful substances falls at a long distance from the source of its formation. According to some data, its rapid dispersion occurs, but, given the intensity of military operations, air pollution is constantly replenished, which, in turn, leads to the deterioration of the ecological state of the soil cover and the state of surface water bodies. It should be noted that all rocket fuels are extremely toxic. So, the debris of shells and missiles found on the field or near targets, almost guaranteed to contain the remains of toxic aviation fuel. In modern solid-fuel engines, a mixture of ammonium perchlorate with aluminum, rubber and other additives is most often used. Combustion or disposal by blasting ballistitis - solid rocket fuel based on cellulose nitrate and nitroether solvents, which are often used in military rocket engines, is accompanied by the formation of a number of toxic components (depending on the type of fuel used in a particular rocket): CO - up to 416.2 g/kg; C - up to 86.4g/kg; Pb - up to 6.7 g/kg; PbO up to 1.8 g/kg; NO - up to 161.6 g/kg; NO_2 - up to 2.9 g/kg; CH_4 - up to 55.0 mg/kg; NH_3 - up to 0.3 g/kg; HNO_3 - up to 0.4 g/kg; HCN - up to 5.2 g/kg. To this mixture is added a mixture of detonation products of substances that initiate the explosion and the explosive substance of the missile warhead itself.

In real conditions, the products of the explosion of the rocket and its fuel can interact with each other, with groundwater, with moist air and oxygen. Therefore, the final chemical composition of the rocket firing products will always be different, depending on the conditions in which the explosion occurred.

Typical substances used for detonation are various lead compounds. It is known that both lead itself and its compounds (such as, oxides PbO, PbO_2) are toxic to the human body and belong to highly dangerous substances.

The real assessment of the current ecological consequences of the war is complicated by the specifics of the military situation, military secrecy about the actual composition of the components and the lack of information about the compounds and substances that are formed during the explosion and burning of rockets. Therefore, today the consequences for the environment from their burning and explosions are almost uncertain.

As for agricultural soils, we note that in order to obtain safe agricultural products, it is necessary to conduct ecological and geochemical surveys with an assessment of land regardless of the distance to the line of active military operations. It is known that at one time, the massive bombing of Yugoslavia led to a change in the climate of this region and for almost three months the air warmed continuously. As a result, atmospheric circulation over Europe was disrupted: drought settled in the Eastern European part, and continuous rains fell in the Western European part. At the same time, all conditions and the slightest circumstances must be taken into account when creating a post-war system of ecological monitoring of agricultural, municipal and other lands.

Unfortunately, today the ecological monitoring of the condition of soils in modern conditions is complicated by active hostilities in the east and south of Ukraine. Therefore, taking into account the danger of environmental assessment, the most effective and safe tool for monitoring war-damaged land is the use of satellite data, which will establish the real state of the land and assess the dynamics of this state using retrospective satellite images with a consistent assessment of changes in time.

Using satellite data, in NDVI spectra, we can estimate the state of destruction of forests, fields, meadows by biomass indicators and with the addition of retrospective images we can track the causal relationship of changes in the state of the environment. If, in addition to this spectrum of remote sensing of the earth, we add other such as SWIR, estimating the amount of water in plants, then it will be possible to determine the degree of damage to plants and carry out measures to restore and preserve what survived.

Using radar satellites, it is possible to assess damage to landscapes with the determination of areas of erosion and destruction of the landscape and ground cover by shelling. Such destruction in the future can affect the deterioration of the entire ecological system, due to contamination of the territories with shells and the deformation of landscape cover, which will be a danger to both people and birds and animals, which are part of the ecological system of these territories.

Through satellite data bases, you can determine the sites of shelling, which will facilitate the process of demining and marking areas contaminated with ammunition. It is important that the use of retrospective satellite data makes it possible to determine the priority and sequence of measures to improve

or restore the normal ecological state of the affected areas. In addition, the use of aerospace images makes it possible to assess the level of damage caused and calculate the amount of possible reparations.

In de-occupied areas, agricultural lands, that has undergone demining requires the introduction of measures to minimize environmental risks. To do this, it is necessary to determine an algorithm of actions that should provide for comprehensive environmental monitoring of the state of soils, determination of potential sources of pollution, the degree of their physical, chemical degradation, establishment of ecotoxicological assessment of local sources of pollution and implementation, if necessary, of all stages of reclamation of the soil cover of agrocenoses for their effective using.

The assessment of the ecological and geochemical state in the areas of active military operations should be carried out by the method of ranking contaminated land according to the degree of damage. It is also necessary to propose the main measures for the post-war restoration of useful soil properties lost during military operations. The scientific and methodological principles of land monitoring based on remote sensing of the Earth and geoinformation technologies should be developed, taking into account regional landscape-geochemical features and types of land use and principles of rational nature management.

To identify the extent of the impact of military aggression on soils, it is necessary to conduct an inventory of damaged soils and changes in the structure of the soil cover. For this, various methods of inventory are used, which can help in assessing the condition of soils. The following sequence of conducting an inventory of the amount of soil damage caused by military actions is considered optimal:

1. Visual inspection. It is a method used to assess the degree of soil damage through its visual inspection. For this, photographs, videos and other visual documentation can be used, as well as inspections can be carried out directly on the ground for the purpose of taking soil samples for further research.

2. Laboratory analysis of soil samples, which will allow obtaining detailed information on the state of the soil and drawing conclusions about restoration works.

3. Geophysical methods: These methods are used to study the physical properties of soil, such as density and composition. Geophysical methods include the electroresistive tomography method and the electromagnetic induction method. As noted above, it is advisable to use satellite data to assess soil damage, changes in landscape and soil cover structure. In addition, the use of geoinformation systems (GIS) for the collection and analysis of soil data allows the integration of different types of information, such as aerial images and field survey data, to create, among other things, soil maps.

Methods of soil restoration after military operations are also advisable to use in a certain order. The necessary stages and types of work that can be carried out to return the soils to their previous state should contain the following components:

1) damage assessment;

2) elimination of the consequences of military actions;

3) restoration of soil structure;

4) restoration of biological diversity in soils;

5) protection of soils from erosion processes and the consequences of physical damage.

Conclusions. The development of military aggression in Ukraine indicates a significant negative impact on the soils and soil cover of certain regions, primarily the south and east of our country. The complex nature of this impact on soils is required by the scientific community together with representatives of the production, to combine of efforts and resources, which will help to minimize the negative impact of military actions on soils and ensure their rehabilitation in the shortest possible time, and our state - recovery.

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